

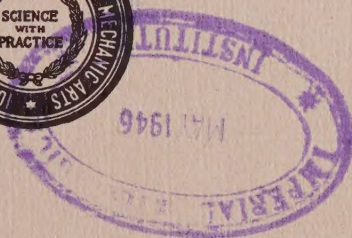
1945

Epiphytology and Control of Sugar Beet Leaf Spot Caused by *Cercospora beticola* Sacc.

By C. M. NAGEL

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE AND
MECHANIC ARTS

BOTANY AND PLANT PATHOLOGY SECTION



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SUMMARY

In eight different spacings, leaf-spot development, sugar beet yield, and sucrose content were studied on a loam soil over a 5-year period, 1933 to 1937 inclusive. In a similar way the number of plants per hill in three different spacings was studied for 4 years.

Wide spacing of the beets in the row gave evidence of reducing the prevalence of leaf spot under condition of moderate infection.

The leaf-spot disease varied in prevalence and destructiveness, depending upon the weather conditions.

In 1933, 1934 and 1937 leaf spot caused less injury to the leaves in the wider than in the narrower spacings.

In 1935, a wet season, a serious epiphytotic of leaf spot occurred, and the disease was prevalent and destructive in all the different spacings.

On the other hand, in 1936, a dry season, little or no leaf spot developed in any of the plots. The differences in yield of plots appeared to be due partly to spacing and partly to leaf spot.

With the possible exception of the 21 x 21-inch spacing in 1937, the yields were not significantly different in the spacings now commonly used in practice, namely, 12 x 21, 18 x 18 and 21 x 21 inches. These three spacings were used in 1935, 1936 and 1937.

The severity of the leaf spot tended to increase as the number of plants per hill increased.

In each year wider spacings produced beets of greater size than in the closer spacings, although the acre yield was usually less. The acre yield was practically the same with one and two plants per hill; with more than two plants per hill the roots were reduced below marketable size.

The percentage sucrose varied only slightly with difference in spacing and number of plants per hill.

Epiphytology and Control of Sugar Beet Leaf Spot Caused by *Cercospora beticola* Sacc.¹

By C. M. NAGEL²

Control measures for *Cercospora beticola* Sacc. in the past usually have been limited to the application of fungicides either as a dust or spray. The use of fungicides for the control of leaf spot on a commercial basis has not always proved effective, practical and economical in the Upper Mississippi Valley. Because of this fact the problem was approached recently from another angle, namely, the development of leaf spot in relation to modified cultural practices. The modification employed in these studies consists of spacing the plants a greater distance apart within and between the rows, thereby inducing a change in environmental conditions, which may directly influence the development of the pathogen. This method is in contrast to the standard method of drill-planting and hand-spacing in which the sugar beet plants are thinned 10 to 12 inches apart in drilled rows.

Melhus and Aikman (8), Lund (7), Vestal and Bell (12) and Vestal (13) in preliminary experiments presented evidence that wider spacing of sugar beets inhibits the leaf-spot organism through greater air circulation, which greatly retards and delays infection. They also reported a lower humidity about the plants in the wider spacing than in the narrower spacings.

In 1930 Melhus and Aikman (8) reported that cross-cultivated beets, 22 x 20 inches, outyielded the normally thinned beets, 22 x 12 inches, 1,963 pounds per acre. During the same year, Vestal and Bell (12) measured the differences in humidity among variously spaced beets and found that when beets in 22-inch rows were spaced 12 inches apart the humidity remained at 100 percent an average of 2 3/10 hours longer than when the beets in similar rows were spaced 20 inches apart. They believed that this longer period of atmospheric saturation was largely responsible for the presence of six times as much leaf spot in

¹ Taken as a portion of a thesis submitted to the faculty of the Graduate College, Iowa State College, in partial fulfillment of the requirements for the degree Doctor of Philosophy. Project 449 of the Iowa Agricultural Experiment Station.

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the 12-inch spacing as in the 20-inch. Vestal (13) reported that beets machine-blocked³ 20 inches in the row yielded 1 9/10 tons per acre more than those blocked 12 inches. Blocking the plants 20 inches in the row retarded the development of the leaf-spot organism 1 month as compared with the 12-inch blocking. He reported also that retarding the leaf spot in the 20-inch blocking reduced the number of dead leaves 16 percent below that of the 12-inch spacing.

European investigators have given attention to the spacing distance for the best yields, but only from an agronomic standpoint and have not taken into consideration the additional serious problem of leaf-spot epiphytotics. Chmelar and Mikolasek (1) and Chmelar, Mikolasek and Simon (2) reported that spacings 45 x 30 and 45 x 25 cm. gave the best yields. They concluded that the distance between plants in the row is of more importance than the distance between rows. Davies (3) in England in 1927-29 favored a closer spacing between rows as well as within the rows. The data showed that wide row distance could not be compensated by narrow spacing in the row; yields increased as row distance decreased down to 16 inches, singling distances of 4 to 10 inches produced no difference in yield of roots. His best yields were obtained from rows 12 to 16 inches apart with the beets not more than 10 inches apart in the row. Garner and Sanders (4, 5) found that as the row distance decreased root yields and sucrose increased, although they found little evidence which indicated that rows narrower than 18 inches were economically feasible. Spacings in the row from 6 to 12 inches furnished no differences in yield of roots or sucrose. These workers also reported that sugar analysis on individual perfect beets showed that very diminutive roots were low in sugar, but that in general sugar percentage decreased with increasing weight of root. The decrease amounted to 1 percent for an increase of 1000 grams in root weight. They further concluded that, over the ordinary range of root size, the relation between sucrose percentage and weight was very slight and of little practical significance.

The following report presents data on the effect that increase in width of spacing over that used in drilled beets has on leaf-spot development, acre yield and percentage sucrose and the results obtained when comparing one, two, three and four plants per hill.

³ Machine-blocked refers to the mechanical spacing of sugar beets within the drilled row. Such spacing is accomplished by crossing the field with a beet cultivator and thereby removing all plants with the exception of small clumps or hills in the rows, usually 18 to 21 inches apart. Thinning clumps to one plant per hill is done by hand labor.

METHODS

The experimental work was conducted on the grounds of the North Iowa Agricultural Experimental Association at Kana-wha, Iowa. The length of the plots varied somewhat from year to year but in general was 50 feet. The width of the plots depended upon the size of the spacings. The spacings used in these experiments consisted of the following: 12 x 12, 12 x 24, 14 x 14, 12 x 21, 18 x 18, 21 x 21, 24 x 24 and 28 x 28 inches. The plots were randomized within the blocks in these experiments. The plots were measured and marked with a specially constructed adjustable marker. All plantings were made with hand planters. The seed was obtained from Germany and was known as the Kleinwanzleben Pioneer strain. Thinning and cultivation were done by hand. Thinning in the experimental plots closely approximated that of commercial growers. The yield data were taken at harvest time, and the calculations were based on a perfect stand. All competitive stand beets present in the plots were harvested for yields.

About 1 month subsequent to thinning, plants of approximately average size were staked and numbered in all the experiments; later in the season leaf-spot records were taken on these plants. Selection of these plants was made systematically throughout the plot. The staked plants made it possible to obtain a complete and detailed account of the amount and rapidity of leaf-spot development, leaf production and defoliation. All leaves killed by the leaf-spot organism were removed from the plant and the number recorded. Therefore, any additional dead leaves present on the plant at the next count were killed by *C. beticola* during that interval. Leaf-spot records in 1933 were taken on a leaf basis. Five classes of necrosis were recorded as follows: healthy, having no leaf-spot symptoms; light, having only a few spots; medium, having a moderate amount; heavy, having the greater portion of the leaf area spotted; and dead, leaves in which the organism induced complete necrosis.

In 1934, 1935, 1936 and 1937 a revised method was used for recording the leaf-spot symptoms. The method is illustrated in fig. 1. To simplify the actual recording of the data the amount of necrosis is represented by numbers ranging from class 0, which represents a healthy leaf, to class 6, which represents a leaf having been killed by the leaf-spot organism. Class 1 represents a leaf possessing from 1 to 10 leaf spots; class 2 represents a leaf possessing from 10 to 50 spots; class 3, 50 to 100 spots per leaf; class 4, 100 spots to areas where the spots were so numerous as to coalesce; class 5 represents a leaf where the spots were sufficiently numerous so that approximately 50 percent of the leaf area was killed.

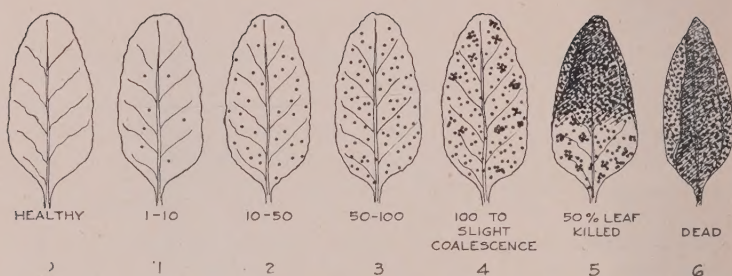


Fig. 1. A diagram of seven classes of sugar beet leaves showing different amounts of leaf-spot necrosis.

For convenience in presenting these data the leaves were divided into two main groups, functional and non-functional. In 1933 healthy, light and medium classes were placed in the group rated as functional, since the leaves in this group were either healthy or were not sufficiently damaged by leaf spot to make them useless to the plant from the standpoint of photosynthesis. Nagel and Leonard (10) have shown that as leaves become more severely affected with leaf spot, their ability to assimilate CO_2 from the air diminishes. Heavy and dead classes were rated as non-functional because the necrotic areas on the leaves in this group were so numerous that the leaves were of no value to the plant for carrying on photosynthesis. During the other years, classes 0, 1, 2, 3 and 4 were considered as functional, and classes 5 and 6 as non-functional leaves.

The leaf-spot data presented in tabular form show the distribution of functional and non-functional leaves on selected sugar beet plants within the experimental plots at specific dates during the season. It should be noted that dead leaves, which were removed from the plants following each leaf count, were included in the total of non-functional leaves in each successive count.

Since the sugar beet tends to maintain a constant leaf area by producing new leaves whenever the older leaves are killed, the average number of functional leaves on the plants in one spacing was considered to be an estimate of the average number of leaves that would be produced by the same number of healthy sugar beet plants under the same environmental conditions. This concept was employed because it was not readily possible to grow check plants free from leaf spot or other damage. The average of the number of functional leaves present on plants at the different record dates in any spacing is considered as the best estimate of the normal complement of leaves on beets planted at that spacing in that season. For each date in a given spacing, the proportion of non-functional leaves is thus expressed

in terms of the estimate of a normal complement of healthy leaves, the ratio of the number of non-functional leaves to the average number of functional leaves for that spacing. Thus, this ratio embodies an expression of time of initiation of disease and amount of destruction of foliage. That is, as the date of initia-

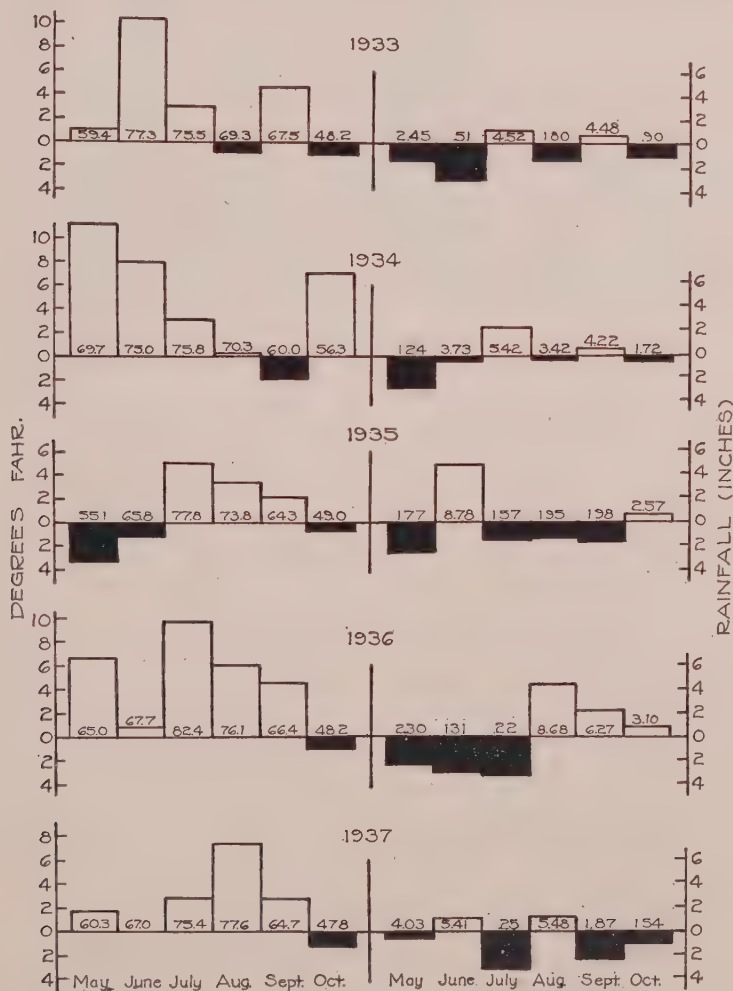


Fig. 2. A summary of temperature and precipitation records for the years 1933-1937 inclusive, Kanawha, Iowa. The value within or above the bar represents the average for the month; the bar represents the departure from normal.

tion of disease is delayed, either due to spacing or other factors, the denominator—average number of functional leaves—is relatively larger. As the degree of destruction of foliage increases, the number of non-functional leaves—the numerator—increases. The composite effect results, in such cases, in a higher value of the ratio.

Climatological data for the 5-year period during which experiments were conducted are presented in fig. 2. These data are according to Reed (10) and were recorded in the vicinity of Kanawha, Iowa, the location of the experimental plots. The data are presented as departures from normal for temperature and rainfall. Figures shown for each month are the average monthly temperatures in degrees Fahrenheit and rainfall in inches. The normal figure used in calculating the departure from normal in 1933 is based on the previous 49-year average; a 50-year average is used for the succeeding years' data.

THE EFFECT OF SPACING ON THE DEVELOPMENT OF THE LEAF-SPOT ORGANISM AND THE SUGAR BEET

EXPERIMENTS IN 1933

The experiments in 1933 were replicated twice with plots 50 feet square. In each of these plots, 15 plants were staked for the purpose of taking leaf-spot records during the season. Three spacings were used: 12 x 12, 12 x 24 and 24 x 24 inches. The approximate number of plants per plot was as follows: 12 x 12-inch, 2,500; 12 x 24-inch, 1,250; and in the 24 x 24-inch spacing, 625. The plantings were made on April 27. The first symptoms of leaf spot appeared in the narrow spacings on June 15 when the plants were in the six to eight-leaf stage.

During the 6-month period from May through October, 1933, temperatures averaged above and precipitation below normal (fig. 2). Throughout the season, however, there were sufficient cloudy and partly cloudy days to provide environmental conditions favorable for the infection by and spread of the leaf-spot organism, as evidenced by the large amount of defoliation that occurred. The severity of the epiphytotic, no doubt, was further influenced by an abundance of inoculum remaining in the soil from the previous year's beet crop (9).

On Aug. 23 the number of dead leaves was greater in the 12 x 12-inch spacing than in the 24 x 24-inch spacing (table 1). Approximately one-fourth as many lightly infected leaves, one-half as many moderately infected and about an equal number of heavily infected leaves were present in the 12 x 12-inch as in the 24 x 24-inch spacing. The plants in the wider spacing carried more functional leaves than those in the narrower spacing

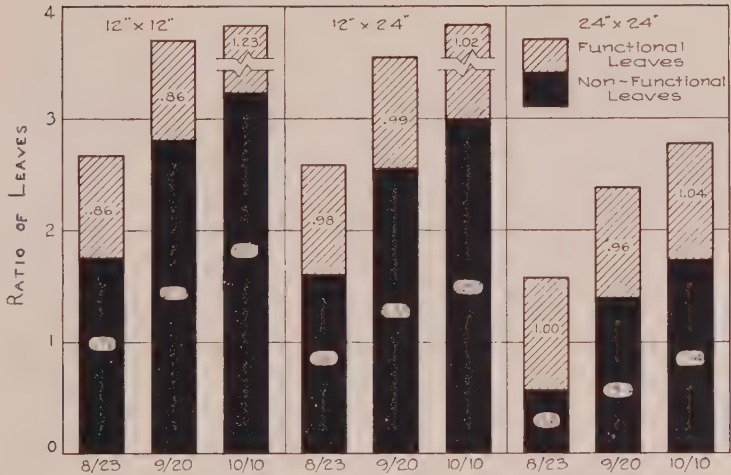


Fig. 3. The ratio of functional and non-functional leaves on sugar beets grown in three different spacings. Kanawha Station, 1933.

on Aug. 23; i. e., an average of 11.4 functional leaves per plant in the former and 5.8 in the latter. Similar tendencies were observed on Sept. 20 and Oct. 10.

TABLE 1. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT IN EACH OF THREE DIFFERENT SPACINGS. KANAWHA STATION, 1933.
30 PLANTS PER SPACING.

Classes of leaf necrosis	12 x 12 inches			12 x 24 inches			24 x 24 inches		
	Aug. 23	Sept. 20	Oct. 10	Aug. 23	Sept. 20	Oct. 10	Aug. 23	Sept. 20	Oct. 10
Healthy	3.7	3.4	6.0	3.9	4.1	5.4	4.6	4.4	7.0
Light	1.0	.9	1.9	1.9	1.0	1.7	4.2	3.0	2.9
Medium	1.1	1.5	0.7	1.7	2.4	0.6	2.6	3.5	1.9
Heavy	1.8	2.9	1.2	2.4	2.4	1.1	1.5	1.8	2.1
Dead	10.0	5.7	4.6	9.8	7.1	4.6	4.9	8.5	4.2
Total functional leaves.....	5.8	5.8	8.6	7.5	7.5	7.7	11.4	10.9	11.8
Total non-functional leaves.....	11.8	18.6	21.5	12.2	19.3	22.6	6.4	15.2	19.7
Total leaves produced.....	17.6	24.4	30.1	19.7	26.8	30.3	17.8	26.1	31.5

These data are expressed graphically in fig. 3 on the basis of the ratio $\frac{\text{no. of non-functional leaves}}{\text{av. no. of functional leaves}}$ for each spacing. The ratio

is only one-third as large in the 24 x 24-inch as in the 12 x 12-inch spacing on Aug. 23, and one-half as large on Sept. 20 and Oct. 10. In terms of this ratio the disease was no more severe on Oct. 10 in the 24 x 24-inch than it was on Aug. 23 in the 12 x 12-inch spacing. Caution must be exercised in interpreting the ratio since the denominator of the ratio increases in the wider spacing and the numerator may, in the early stages of dis-



Fig. 4. Healthy and diseased sugar beet plants. On the left is a healthy plant with a normal set of leaves and low crown. The plant on the right has been seriously damaged by the *Cercospora* leaf-spot organism and shows a comparatively small number of living leaves and many dead leaves at base of crown. The leaves killed by the organism result in a high crown, which in harvesting is removed at the point indicated by the white line. The root of the diseased plant is smaller than the root of the healthy plant.

ease development, be lower in the wider spacings. It is believed that the lower ratio of non-functional leaves expresses the degree of control at the widest spacing. That is, the delay in initiation of disease, which results from more leaves being necessary to overlap in the wide spacing and provide favorable environmental conditions for the pathogen, is contained in the larger denominator or reference point, while the decreased foliar destructiveness of the pathogen on the host is contained in a smaller numerator. From our knowledge of disease relationships in general this ratio would serve to represent the resultant seriousness of the disease on the sugar beet plants.

It may be well to point out that the relative value of the ratio on Aug. 23 represents the delay in initiation of disease, which is extremely important in a consideration of foliage destruction. This is indicated further by the apparently similar increase in disease at all spacings, as indicated by the values of the ratio at subsequent dates. The effect of wider spacing in 1933 was then to delay infection and hence allow the maintenance of a larger number of functional leaves at all times, as well as to lower the number of leaves rendered non-functional per functional leaf

during the season. Note that the number of functional leaves is fairly constant within a spacing.

The effect of the leaf-spot organism on a sugar beet plant is shown in fig. 4. With increased defoliation the crown of the beet elongates (beet at right) and assumes a conical shape. This portion must be removed in topping and thus results in a reduction in tonnage.

The yield for each spacing is shown in table 2. The 12 x 12-inch spacing yielded less tonnage than the wider spacing. Whether this difference in tonnage was due to differences in amount of leaf spot or to spacing was not established, because it was impossible to carry check experiments where leaf spot was absent. The evidence is conflicting. The intermediate spacing was intermediate in amount of leaf spot but greatest in yield.

TABLE 2. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF ROOTS OF SUGAR BEETS GROWN IN THREE DIFFERENT SPACINGS. KANAWHA STATION, 1933.

Spacing (inches)	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
12 x 12	43,560	0.53	12.3	11.6
12 x 24	21,780	1.28	10.7	13.9
24 x 24	10,890	2.48	11.0	13.5

EXPERIMENTS IN 1934

The plots were 50 feet square with four different spacings replicated twice. The following spacings were used: 12 x 12, 12 x 24, 24 x 24 and 28 x 28 inches. The approximate number of plants per plot was as follows: 12 x 12-inch, 2,500; 12 x 24-inch, 1,250; 24 x 24-inch, 625; and the 28 x 28-inch spacing contained approximately 484 plants per plot. The plantings were made on May 10. Leaf-spot records were taken from 45 representative plants staked at random in each plot. The first leaf-spot symptoms were observed on June 25, just subsequent to thinning of the stand.

Leaf spot in 1934 was much less destructive than during the previous year. During the 6-month period from May through October, temperatures were generally unusually high with a monthly average of 0.2° to 11.3° F. above normal, except in September when the temperature was about 2° below normal (fig. 2). The growing season of 1934 was one of the warmest recorded in the history of the Iowa Weather Bureau. Probably even more important than the high temperatures was the subnormal monthly precipitation beginning in October, 1933, and extending to July, 1934. During this 9-month period there was a deficiency of 7.02 inches. The combination of high temperature and rainfall deficiency seemed to inhibit the development of the leaf-spot organism and the growth of the beet crop.

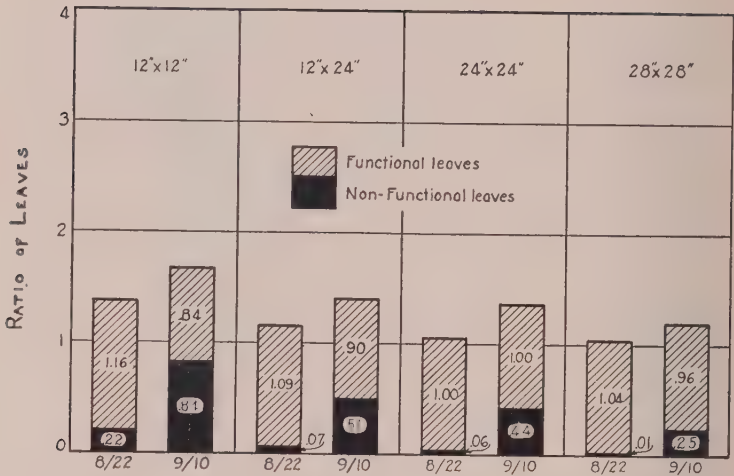


Fig. 5. The ratio of functional and non-functional leaves on sugar beets grown in four different spacings. Kanawha Station, 1934.

Leaf spot on Aug. 22 was light; most of it occurred after rains on Aug. 8. The number of healthy or 0-class leaves increased with each advance in width of spacing (table 3). There was much the same trend in the class 1 leaves. The 28 x 28-inch spacing showed a decrease in classes 2, 3, 4, 5 and 6 as compared with the corresponding classes in the 12 x 12-inch, showing that the general health of the plants in the wider spacing was superior to that of the plants in the narrower spacing. There was a steady decrease in the amount of leaf spot present with wider spacing. A similar trend of decrease in the development of the leaf-spot organism on plants in the wider spacings was evident on Sept. 10. In fact, the plants in the 12 x 12-inch spacing had twice as many leaves rendered non-functional by that time as the plants in the 28 x 28-inch spacing. The action of spacing in delaying the killing of the leaves by the leaf-spot organism was very evident in the later date at which the first leaf was rendered non-functional and in the lower number of leaves rendered non-functional by Sept. 10.

The ratios of non-functional to average number of functional leaves in the four different spacings and at two dates are presented graphically in fig. 5. The decrease in the ratios with increase in spacing was almost linear. There was again a delay in rendering the first leaf non-functional in the wider spacing. It is further believed that, in part at least, the larger number of

functional leaves in the wider spacings is the result of the later incidence of the disease in a destructive form.

Sucrose and tonnage were not greatly different, although the number of plants per acre ranged from 8,001 in the 28 x 28 spacing to 43,560 plants in the 12 x 12 spacing (table 4). Moisture and temperature conditions in 1934 seriously interfered with the development of the plants, and as a result the yields were low in all spacings.

TABLE 3. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT IN EACH OF FOUR DIFFERENT SPACINGS. KANAWHA STATION, 1934.
90 PLANTS PER SPACING.

Classes of leaf necrosis	12 x 12 in.		12 x 24 in.		24 x 24 in.		28 x 28 in.	
	Aug. 22	Sept. 10	Aug. 22	Sept. 10	Aug. 22	Sept. 10	Aug. 22	Sept. 10
0	6.1	9.4	7.9	10.8	9.1	12.5	10.5	12.3
1	1.7	0.2	4.8	0.3	4.7	0.4	8.6	0.4
2	3.0	0.3	4.2	0.5	5.1	0.7	2.8	0.8
3	2.9	0.6	2.3	1.7	1.6	1.6	0.8	3.6
4	3.6	2.0	1.4	3.8	1.0	6.3	0.5	4.2
5	0.9	1.5	0.6	1.5	0.5	1.7	0.0	1.3
6	2.3	8.8	0.8	7.4	0.7	7.2	0.1	4.2
Total functional leaves.....	17.3	12.5	20.6	17.1	21.5	21.5	23.2	21.3
Total non-functional leaves.....	3.2	12.6	1.4	9.7	1.2	9.6	0.1	5.6
Total leaves produced.....	20.5	25.1	22.0	26.8	22.7	31.1	23.3	26.9

TABLE 4. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF ROOTS OF SUGAR BEETS GROWN IN FOUR DIFFERENT SPACINGS.
KANAWHA STATION, 1934.

Spacing (inches)	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
12 x 12	43,560	0.39	14.4	8.5
12 x 24	21,780	0.79	14.3	8.6
24 x 24	10,890	1.40	13.7	7.6
28 x 28	8,001	1.92	13.4	7.7

EXPERIMENTS IN 1935

In 1935, the experiment consisted of six spacings with six replications in complete randomized blocks. Plots were 50 feet long. The number of rows per plot varied from 6 to 12, depending upon width of spacing. Although the widths of the plots were variable, they were sufficiently large to contain a minimum of 150 plants each. This number provided sufficient plants to record leaf spot, yield and percentage sucrose. The plantings were made on April 18 and 19. The stand on June 1 was approximately 95 percent. The following six spacings were used in this experiment: 14 x 14, 12 x 21, 18 x 18, 21 x 21, 24 x 24 and 28 x 28 inches. Fifteen representative plants upon which leaf-spot records were taken at intervals were staked and numbered in each plot.

Temperatures were slightly above normal during July, August and September, and precipitation was above normal during June (fig. 2). Although the rainfall after June was slightly below

TABLE 5. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT IN EACH OF SIX DIFFERENT SPACINGS.
KANAWHA STATION, 1935. 90 PLANTS PER SPACING.

	14 x 14 inches				12 x 21 inches				18 x 18 inches			
	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16
Classes of leaf necrosis												
0	18.9	8.5	6.3	4.2	19.5	8.8	7.1	5.3	19.9	8.9	6.7	5.2
1	.....	8.8	0.5	2.0	.....	6.8	0.5	2.1	.....	7.0	0.4	2.4
2	.....	2.4	0.7	1.2	.....	2.6	0.5	1.0	.....	2.8	0.6	1.1
3	.....	1.2	1.2	0.9	.....	1.5	1.3	1.1	.....	1.0	1.3	1.3
4	.....	0.3	4.6	1.0	.....	0.4	6.2	1.0	.....	0.5	5.7	0.7
5	.....	.....	4.8	1.1	.....	.....	5.0	1.2	.....	.....	5.3	1.2
6	.....	.....	14.9	18.7	.....	.....	13.0	19.9	.....	.....	14.8	19.0
Total functional leaves.....	18.9	21.2	13.3	9.3	19.5	20.1	15.6	10.5	19.9	20.2	14.7	10.7
Total non-functional leaves.....	.....	.....	19.7	34.7	.....	.....	20.0	36.1	.....	.....	20.1	35.0
Total leaves produced.....	18.9	21.2	33.0	44.0	19.5	20.1	35.6	46.6	19.9	20.2	34.8	45.7

	21 x 21 inches				24 x 24 inches				28 x 28 inches			
	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16
Classes of leaf necrosis												
0	21.2	12.5	6.5	5.7	20.9	13.6	6.5	5.5	21.4	14.5	7.2	5.8
1	.....	9.2	0.7	2.5	.....	7.4	0.7	2.6	.....	8.7	1.0	2.8
2	.....	2.1	0.8	1.4	.....	1.8	0.9	1.3	.....	1.6	1.0	1.5
3	.....	1.0	1.7	1.1	.....	0.7	1.9	1.4	.....	0.3	2.2	1.3
4	.....	0.4	8.1	1.1	.....	0.1	8.8	1.1	.....	0.2	9.6	1.3
5	.....	.....	5.5	1.3	.....	.....	5.7	1.4	.....	.....	6.1	1.6
6	.....	.....	14.1	18.1	.....	.....	13.1	21.3	.....	.....	11.7	23.5
Total functional leaves.....	21.2	25.2	17.8	11.8	20.9	23.6	18.8	11.9	21.4	25.3	21.0	12.7
Total non-functional leaves.....	.....	.....	19.6	33.5	.....	.....	18.8	35.8	.....	.....	17.8	36.8
Total leaves produced.....	21.2	25.2	37.4	45.3	20.9	23.6	37.6	47.7	21.4	25.3	38.8	49.5

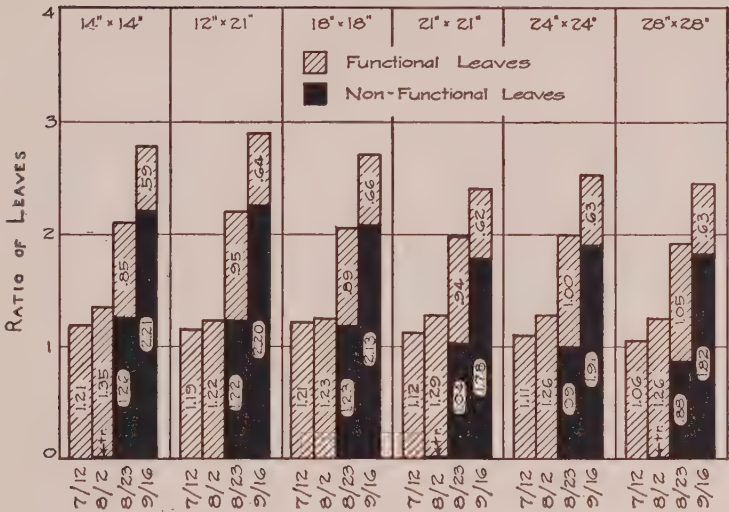


Fig. 6. The ratio of functional and non-functional leaves on sugar beets grown in six different spacings. Kanawha Station, 1935.

normal, the excess moisture of 4.84 inches during June maintained a high soil moisture.

Cloudy and partly cloudy days were numerous. In June, 22 days out of a possible 30 were either cloudy or partly cloudy. A leaf-spot epiphytotic occurred generally in the state, indicating that such environmental conditions were very favorable to the development of the leaf-spot organism.

The first leaf-spot symptoms were observed on July 28. This was about 1 month later than in 1933 and 1934. In spite of the late start the leaf-spot damage was severe. The amount of damage was fairly uniform throughout the various spacings (table 5).

The ratio of non-functional to the average number of functional leaves in the six spacings on the last three dates are presented in fig. 6. By Aug. 23 the ratio was approximately 1 in all spacings, showing a drop from 1.20 plus in the 18 x 18-inch and closer spacings to .88 in the 28 x 28-inch spacings. This decrease in the ratio is as much due to a more rapid production of leaves and resultant maintenance of more functional leaves in the wider spacing as to the slightly lower number of leaves rendered non-functional. This is further illustrated in the ratios on Sept. 16 when the 18 x 18-inch ratio was 2.13 while that for the 28 x 28-inch spacing was 1.82, in spite of the fact that there were 1.8 more dead leaves per plant at the wider spacing.

The mean weights, percentage sucrose and yields are presented in table 6. The highest yield occurred in the 14 x 14-inch spacing. To what extent the leaf-spot disease reduced the yield in the different plots could not be determined because no plots were available where leaf spot was absent. Since the leaf-spot disease developed rapidly and generally in all plots, it is probably safe to assume that a decrease in yield was general in all plots. The weather conditions were apparently favorable in 1935 for the growth of the beet plant; nevertheless, the root weight was low. This low root weight is believed to be due to the injury to the leaves caused by the leaf-spot organism, which reached serious epiphytotic proportions during the latter half of the growing season. The differences in plot yields may be due to differences in total growth previous to the defoliation and to the difference in number of plants in the different plots.

TABLE 6. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF ROOTS OF SUGAR BEETS GROWN IN SIX DIFFERENT SPACINGS. KANAWHA STATION, 1935.

Spacing (inches)	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
14 x 14	32,003	0.68	14.58	10.93
12 x 21*	24,891	0.71	15.05	8.84
18 x 18	19,560	0.91	14.80	8.94
21 x 21	14,223	1.23	14.51	8.72
24 x 24	10,890	1.26	14.13	6.87
28 x 28	8,001	1.52	14.21	6.10

* Standard spacing used by growers.

EXPERIMENTS IN 1936

Six spacings, each replicated six times, were used in the experimental plots in 1936. Plot size, spacings and number of plants for taking leaf-spot records were the same as in 1935. The planting was made on May 1.

Weather conditions in 1936 were such that little or no leaf spot appeared in either the experimental plots or in the growers' fields. Temperatures were above normal, precipitation below normal, particularly during the months of May, June and July. There were fewer cloudy and partly cloudy days than occurred during the previous year.

Drouth associated with high temperatures lasted from June 25 to Aug. 20, which permitted a minimum of plant growth and also retarded the development of the pathogen. Abundant rains fell after Aug. 20, and temperatures at night remained relatively low. A light frost occurred during the last week in August, and the night temperatures ranged from 55° to 65° F. most of the time after Aug. 20. As little leaf spot developed in the plots in 1936, the low temperatures were considered to be unfavorable for the development of the pathogen.

In this season of 1936, the data in table 7 afford an opportunity to study the effect of spacing on sucrose percentage and yield in the absence of leaf spot. The sucrose percentage was not significantly different in the different plots. The 14 x 14-inch spacing produced a greater yield than the wider spacing in the absence of leaf-spot injury under the growing conditions that prevailed in 1936.

TABLE 7. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF ROOTS OF SUGAR BEETS GROWN IN SIX DIFFERENT SPACINGS, KANAWHA STATION, 1936.

Spacing (inches)	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
14 x 14	32,003	0.96	14.21	15.37
12 x 21	24,891	1.16	14.31	14.44
18 x 18	19,560	1.43	13.90	14.02
21 x 21	14,223	1.85	13.73	13.26
24 x 24	10,890	1.91	13.63	10.42
28 x 28	8,001	2.25	13.65	9.01

EXPERIMENTS IN 1937

The same spacings were used as in the previous year with five replications instead of six. The plot size and the number of plants per plot staked for taking leaf-spot records were the same as in 1936. The plantings were made on May 6. The balance of May and June were wet, which retarded the development of the beets.

The temperature was about normal for May, June and October, and above normal during July, August and September. Precipitation was below normal. The cloudy days or partly cloudy days during the 6-month period were fewer in number per month in comparison with the records of previous years.

The prevalence and destructiveness of leaf spot in 1937 was much greater than in 1936 but not as severe as in 1935.

On Aug. 25 the number of leaves in classes 0 and 1 were observed to increase with the width of spacing (table 8). Leaf classes 3, 4, 5 and 6 decreased in number with increased spacing with the exception of the 21 x 21-inch spacing. The data on Aug. 25 show that the pathogen had developed in greater abundance in the closer spacings than in the wider spacings.

The number of class 0 and 1 leaves recorded on Sept. 9 showed a trend similar to that recorded on Aug. 25. The number of leaves in classes 3, 4 and 5 on Sept. 9, in contrast to the record on Aug. 25, showed distinct tendencies for increased leaf-spot damage with wider spacing. This condition was reached earlier with narrow spacing, showing that the destruction by the organism was definitely delayed under conditions of wider spacing.

TABLE 8. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT IN EACH OF SIX DIFFERENT SPACINGS.
KANAWHA STATION, 1937. 75 PLANTS PER SPACING.

Classes of leaf necrosis	14 x 14 inches			12 x 21 inches			18 x 18 inches			21 x 21 inches			24 x 24 inches			28 x 28 inches		
	Aug. 25	Sept. 9	Sept. 9	Aug. 25	Sept. 9	Sept. 9	Aug. 25	Sept. 9	Sept. 9	Aug. 25	Sept. 9	Sept. 9	Aug. 25	Sept. 9	Sept. 9	Aug. 25	Sept. 9	Sept. 9
0	8.0	9.1	9.2	8.5	9.2	9.9	9.7	9.9	9.9	9.1	9.5	9.5	9.8	10.1	10.1	9.4	10.8	10.8
1	12.6	1.6	1.6	13.4	1.6	2.1	17.3	2.1	2.1	15.4	2.2	2.2	18.0	2.9	2.9	20.6	3.0	3.0
2	3.1	1.0	1.2	3.5	1.2	3.6	3.6	1.4	1.4	3.1	1.6	1.6	1.6	3.1	3.1	1.1	2.3	2.3
3	1.7	3.5	4.6	1.3	4.6	0.5	0.5	6.8	6.8	1.0	6.2	6.2	0.3	9.4	9.4	0.2	8.5	8.5
4	0.9	4.0	4.2	0.7	4.2	0.3	0.3	4.8	4.8	0.8	4.8	4.8	0.2	4.2	4.2	0.3	5.4	5.4
5	0.4	1.5	2.4	0.3	2.4	0.1	0.1	2.2	2.2	0.3	2.3	2.3	0.1	1.7	1.7		2.8	2.8
6		12.8	13.6	0.2	13.6	0.1	0.1	12.9	12.9	0.1	12.0	12.0		8.9	8.9		8.4	8.4
Total functional leaves	26.3	19.2	20.8	27.4	20.8	31.4	31.4	25.0	25.0	29.4	24.3	24.3	29.9	29.7	29.7	31.6	30.0	30.0
Total non-functional leaves	0.4	14.3	16.2	0.5	16.2	0.2	0.2	15.2	15.2	0.4	14.4	14.4	0.1	10.6	10.6		11.2	11.2
Total leaves produced	26.7	33.5	37.0	27.9	37.0	31.6	31.6	40.2	40.2	29.8	38.7	38.7	30.0	40.3	40.3	31.6	41.2	41.2

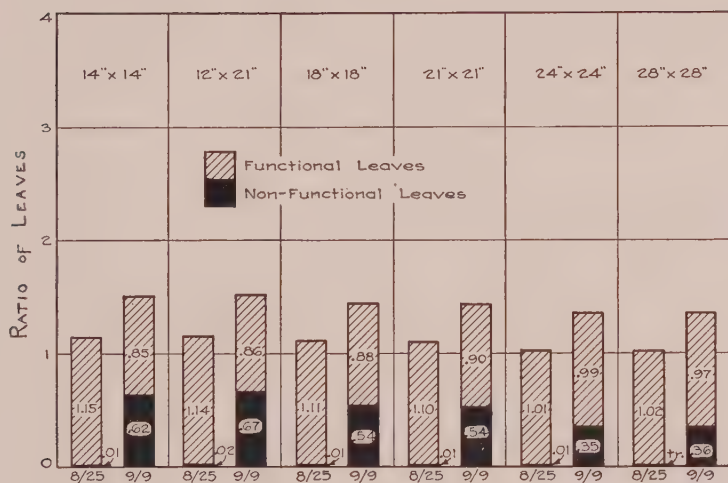


Fig. 7. The ratio of functional and non-functional leaves on sugar beets grown in six different spacings. Kanawha Station, 1937.

The number of leaves in class 6 decreased in the wider spacings. The ratios of non-functional to the average number of functional leaves per spacing present on Aug. 25 and Sept. 9 are illustrated in fig. 7. The lower ratios at the wider spacings on Sept. 9 are partly due to a larger number of functional leaves on the plants at these spacings. Since, however, the number of functional leaves remained constant at the wider spacings, the lower ratios are believed to indicate the absence of as serious an effect of the leaf-spot organism on the photosynthetic area of the plant as at the narrower spacings.

Table 9 presents the data obtained on mean weight, percentage sucrose and yield. The average percentage of sucrose was low because the sugar beet samples for these tests were harvested following a 1-inch rainfall. It is known that sugar percentage drops after a rain (6). The beets take up an excess of water, thus bringing about a greater dilution of the sugar in the plant juice. There appeared to be no significant difference in the percentage sucrose of beets taken from different spacings.

It is apparent from the yield data in table 9 that the limited defoliation did not influence the yield seriously in the 14 x 14-inch spacing because 17.12 tons per acre is a very good yield for Iowa. The yield was distinctly higher in the 14 x 14-inch spacing than in the wider spacings. It is notable, also, that both the level

of yield and its trend in the spacings are practically the same as in 1936.

TABLE 9. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF ROOTS OF SUGAR BEETS GROWN IN SIX DIFFERENT SPACINGS. KANAWHA STATION, 1937.

Spacing (inches)	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
14 x 14	32,003	1.07	11.32	17.12
12 x 21	24,891	1.15	11.74	14.36
18 x 18	19,560	1.51	11.56	14.76
21 x 21	14,223	1.54	11.18	10.98
24 x 24	10,890	2.26	11.78	12.31
28 x 28	8,001	2.49	11.52	9.97

THE EFFECT OF MORE THAN ONE BEET PER HILL COMBINED WITH WIDER SPACING ON CERCOSPORA LEAF-SPOT DEVELOPMENT, PERCENTAGE SUCROSE AND YIELDS

It has been found that the wider spacing of sugar beets retards the development of the leaf-spot organism, but yields may be decreased. The decrease in yield is due to the decrease in the number of plants per acre although this is partly compensated by the accompanying increase in size of beet. For example, in the 12 x 21-inch spacing there are 24,891 plants per acre, and in the 28 x 28-inch spacing there are 8,001, assuming a perfect stand in both cases. There is a decrease of two-thirds in the number of plants per acre in the wider spacing. With this in view, an experiment was planned to determine what the effect would be on the development of the *Cercospora* leaf-spot organism and on the yield by increasing the number of plants per hill without changing the spacing.

EXPERIMENTS IN 1934

The plan of the plots was the same as that used in the previous experiments except that the number of plants per hill was increased to two, three and four in 28 x 28-inch spacings in certain plots. Two replications were used in the experiments in 1934, and the plantings were made on May 10. Planting, thinning and recording of leaf-spot and yield data were similar to the 1934 experiments in which only one plant per hill was used. Climatological data have been presented earlier in this bulletin (fig. 2).

The number of leaves recorded on Sept. 10 as damaged by the leaf-spot organism decreased only slightly as the number of plants per hill was increased (table 10). The actual increase in seriousness of damage because of fewer leaves being formed under the more crowded conditions is indicated in fig. 8, which

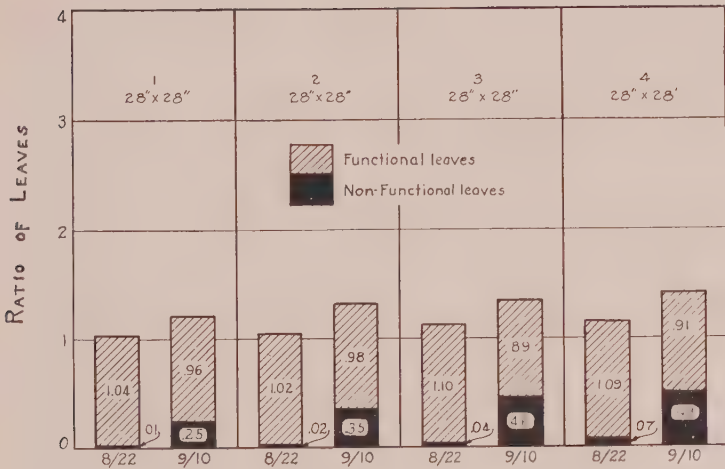


Fig. 8. The ratio of functional and non-functional leaves when one, two, three and four sugar beets per hill were grown in a 28 x 28-inch spacing. Kanawha Station, 1934.

shows the ratios of non-functional to average number of functional leaves. While the number of non-functional leaves per plant is less with four plants than with one plant per hill, it is

TABLE 10. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT HAVING DIFFERENT AMOUNTS OF NECROSIS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN A 28 x 28-INCH SPACING. KANAWHA STATION, 1934.

Classes of leaf necrosis	Number of plants per hill							
	(1)		(2)		(3)		(4)	
	Aug. 22	Sept. 10	Aug. 22	Sept. 10	Aug. 22	Sept. 10	Aug. 22	Sept. 10
0	10.5	12.3	7.5	9.0	5.3	6.4	4.9	5.2
1	8.6	0.4	4.3	0.5	2.3	0.3	2.0	0.3
2	2.8	0.8	3.2	0.6	3.8	0.4	2.0	0.2
3	0.8	3.6	1.1	2.0	1.2	1.0	1.1	0.7
4	0.5	4.2	0.6	3.9	0.7	2.6	0.6	2.5
5		1.3	0.2	1.2	0.4	1.0	0.4	0.7
6	0.1	4.2	0.2	4.4	0.2	4.3	0.2	3.7
Total functional leaves.....	23.2	21.3	16.7	16.0	13.3	10.7	10.6	8.9
Total non-functional leaves.....	0.1	5.6	0.4	5.8	0.6	5.5	0.6	4.6
Total leaves produced.....	23.3	26.9	17.1	21.8	13.9	16.2	11.2	13.5

TABLE 11. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF SUGAR BEET ROOTS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN A 28 x 28-INCH SPACING. KANAWHA STATION, 1934.

Spacing (inches)	Plants per hill	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
28 x 28	1	8,001	1.92	13.4	7.7
28 x 28	2	16,002	0.90	14.6	7.2
28 x 28	3	24,003	0.59	13.9	7.1
28 x 28	4	32,004	0.39	14.5	6.2

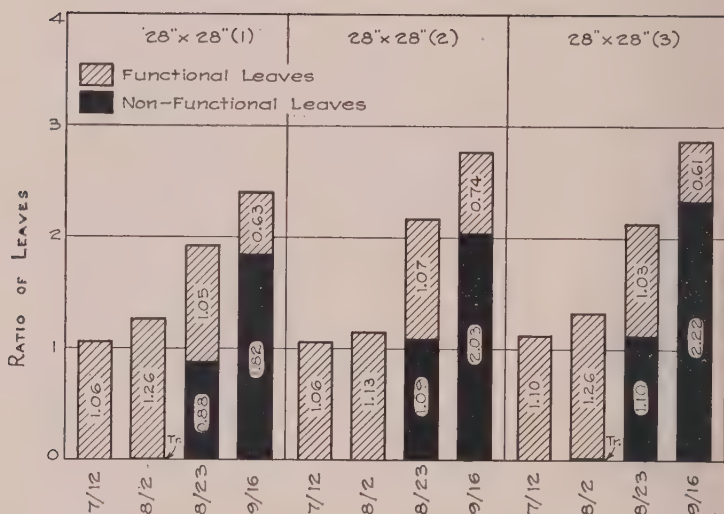


Fig. 9. The ratio of functional and non-functional leaves when one, two and three sugar beets per hill were grown in a 28 x 28-inch spacing. Kanawha Station, 1935.

believed that the ratio indicates the greater damage to the host since the more crowded plants have fewer leaves and thus would be more affected by the loss of a leaf.

Mean weight, percentage sucrose and yield when one to four plants per hill were grown are presented in table 11. In 1934, sugar beet yields were below normal because of the dry, hot weather conditions as stated above. One plant per hill gave larger beets, while with four plants per hill the roots were too small to be desirable for processing. Two plants per hill produced beets that were uniform in size and well shaped. Apparently the competition in the hills of four plants and the decreased number of functional leaves had a markedly detrimental effect on the development of the plants.

EXPERIMENTS IN 1935

Data and observations in 1934 showed that it was inadvisable to leave four plants per hill in a 28 x 28-inch spacing, as the beet roots from such experiments proved to be too small for commercial use. In addition, the crowded conditions in the hill made environmental factors more favorable to the pathogen. Four plants per hill were omitted from the experiments in 1935. Three replications were used, and the size of plots was the same as that of the previous season. The plots were planted on April 18.

TABLE 12. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT HAVING DIFFERENT AMOUNTS OF NECROSIS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN A 28 x 28-INCH SPACING. KANAWHA STATION, 1955.

Classes of leaf necrosis	Number of plants per hill											
	(1)				(2)				(3)			
	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16	July 12	Aug. 2	Aug. 23	Sept. 16
0	42.9	29.1	14.4	11.6	35.3	15.7	14.4	11.8	35.6	20.4	13.2	10.5
1		17.4	2.1	5.3		16.2	1.2	6.2		15.0	1.4	3.5
2		3.2	2.0	3.0		4.4	1.3	2.2		4.0	1.3	2.0
3		0.6	4.4	2.6		1.0	2.6	2.0		1.4	2.5	2.0
4		0.4	19.2	2.6		0.3	16.1	2.6		1.0	14.9	1.6
5			12.2	3.2			13.0	3.1		0.2	10.0	4.6
6			23.4	46.9			23.4	41.1			25.4	41.8
Total functional leaves	42.9	50.7	42.1	25.1	35.3	37.6	35.6	24.8	35.6	41.8	33.3	19.6
Total non-functional leaves			35.6	73.5			36.4	67.6		0.2	35.4	71.8
Total leaves produced	42.9	50.7	77.7	98.6	35.3	37.6	72.0	92.4	35.6	42.0	68.7	91.4

TABLE 13. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF SUGAR BEET ROOTS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN A 28 x 28-INCH SPACING. KANAWHA STATION, 1935.

Spacing (inches)	Plants per hill	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
28 x 28	1	8,001	1.52	14.21	6.10
28 x 28	2	16,002	0.91	14.90	7.32
28 x 28	3	24,003	0.54	14.25	6.54

Fifteen representative plants, on which leaf-spot records were taken, were staked and numbered in each plot. Weather conditions in 1935 were highly favorable to the leaf-spot organism.

Where only one beet per hill was grown, slightly more leaves were damaged by the organism than with three beets per hill (table 12). With each additional plant per hill, slight decreases in number of leaves per plant occurred. The actual effect on the beets because of fewer leaves being formed under the more crowded conditions is more clearly observed in fig. 9. The ratios of non-functional to the average number of functional leaves on Aug. 23 increased with each additional plant per hill. The same trend in the records occurred on Sept. 16.

The size of the beets decreased as the number of beets per hill increased (table 13), but the yield differences clearly were not significant. Beets grown at the rate of three plants per hill, however, would suffer considerable loss in "tare" because of their undersize.

EXPERIMENTS IN 1936

In the 1936 experiments, only one and two plants per hill were used in 21 x 21-inch and 28 x 28-inch spacings. The planting was made on May 1 and contained four replications. Leaf-spot records were taken on 15 representative plants.

No leaf-spot symptoms occurred in the experimental plots during 1936 because the drouth, which lasted until the middle of August, produced environmental conditions wholly unfavorable to the leaf-spot organism. Although abundant rains fell after Aug. 20, the temperature remained too low, 55° to 65° F. during the nights, for favorable development of the pathogen.

The slight differences in yield with one and two plants per hill are clearly not significant.

TABLE 14. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF SUGAR BEET ROOTS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN TWO DIFFERENT SPACINGS. KANAWHA STATION, 1936.

Spacing (inches)	Plants per hill	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
21 x 21	1	14,223	1.85	13.73	13.26
21 x 21	2	28,446	0.96	14.31	13.60
28 x 28	1	8,001	2.25	13.65	9.01
28 x 28	2	16,002	1.13	14.10	9.07

EXPERIMENTS IN 1937

Because of previous results on the development of the leaf-spot organism, in 1937 the 24 x 24-inch spacing was included with the 21 x 21- and 28 x 28-inch spacings. Four replications were used, and the plantings were made on May 6. Leaf-spot records were taken on 15 representative plants.

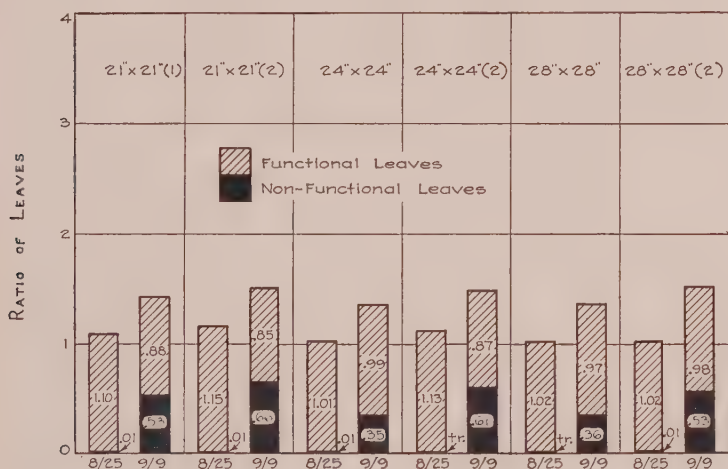


Fig. 10. The ratio of functional and non-functional leaves when one and two sugar beets per hill were grown in three different spacings. Kanawha Station, 1937.

The development of the leaf-spot organism on one and two plants per hill is presented in table 15 and in fig. 10. Practically no non-functional leaves were recorded in either the singles or doubles on Aug. 25. The least damaging development of the organism occurred with one plant per hill in the 24 x 24- and 28 x 28-inch spacings. With decrease in width of spacing, leaf spot tended to increase, but not markedly.

The root weights as recorded in table 16 decreased slightly less than half in the case of two plants per hill.

TABLE 16. MEAN WEIGHT, PERCENTAGE SUCROSE AND YIELD OF SUGAR BEET ROOTS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN THREE DIFFERENT SPACINGS. KANAWHA STATION, 1937.

Spacing (inches)	Plants per hill	Plants per acre	Weight per beet (pounds)	Percentage sucrose	Yield (tons per acre)
21 x 21	1	14,223	1.54	11.18	10.98
21 x 21	2	28,446	0.99	11.30	12.65
24 x 24	1	10,890	2.26	11.78	12.31
24 x 24	2	21,780	1.16	11.40	12.68
28 x 28	1	8,001	2.49	11.52	9.97
28 x 28	2	16,002	1.47	10.90	11.79

TABLE 15. THE AVERAGE NUMBER OF LEAVES PER SUGAR BEET PLANT HAVING DIFFERENT AMOUNTS OF NECROSIS WHEN ONE OR MORE PLANTS PER HILL WERE GROWN IN THREE DIFFERENT SPACINGS. KANAWHA STATION, 1937.

Classes of leaf necrosis	21 x 21 inches				24 x 24 inches				28 x 28 inches			
	(1)		(2)		(1)		(2)		(1)		(2)	
	Aug. 25	Sept. 9	Aug. 25	Sept. 9	Aug. 25	Sept. 9	Aug. 25	Sept. 9	Aug. 25	Sept. 9	Aug. 25	Sept. 9
0	11.3	11.8	8.4	9.2	12.3	12.6	9.1	9.4	11.8	13.5	8.5	9.6
1	19.3	2.8	11.9	1.6	22.5	3.6	15.8	1.9	25.8	3.8	13.4	2.3
2	3.9	2.0	3.4	1.0	2.1	3.8	2.1	0.8	1.4	2.9	2.0	1.9
3	1.3	7.8	1.0	2.9	0.4	11.8	0.7	4.0	0.3	10.6	0.6	5.7
4	1.0	6.0	0.6	3.8	0.3	5.2	0.3	5.4	0.4	6.8	0.3	4.5
5	0.4	2.9	0.1	2.7	0.2	2.1	0.1	3.7	0.1	3.5	0.2	3.0
6	0.1	15.0	0.1	11.8		11.1	0.1	11.7		10.5		9.9
Total functional leaves	36.8	30.4	25.3	48.5	37.6	37.0	28.0	21.5	39.7	37.6	24.8	24.0
Total non-functional leaves	0.5	18.0	0.2	14.6	0.2	13.2	0.2	15.5	0.1	14.0	0.2	12.9
Total leaves produced	37.3	48.4	25.5	33.1	37.8	50.2	28.2	37.0	39.8	51.6	25.0	36.9

The number of roots produced, however, was sufficiently large to result in a comparable yield. The percentage of sucrose again did not differ significantly between the different plots. The percentage sucrose was low because a 1-inch rain fell just preceding harvest.

DISCUSSION

There are three interesting aspects of the sugar beet spacing problem that are evident as a result of a general review of the data obtained. The most consistent fact from the overall data is that an increase in spacing causes a steady increase in size of the beets. The outstanding feature of this increase is that it remains fairly steady regardless of the season or the intensity of leaf spot. In one of the five seasons this increase in size of beet was sufficient to overcome the reduced number of beets, resulting in a yield equal to or more than that of the small beets at closer spacings. The reasons for this variation are thought to be due to leaf-spot reduction of leaf surface, spacing effects on beet growth and general reaction of sugar beets to the seasonal environments.

The effect of wider spacing of the beets on leaf spot, as a method of control, appears to be evident in seasons of moderate leaf-spot infection. When there is a severe epiphytotic starting early in the season, spacing is not sufficient by itself to control leaf spot.

The use of doubles at the wide spacings appears to be a feasible cultural method. It is believed that there is some control of leaf spot and that the doubles, yielding sizable beets may, under commercial conditions, produce a greater acre yield, because the complete loss of hills that occurs so frequently in machine culture would undoubtedly be less when doubles are left rather than singles.

